RADIATION DAMAGE STUDIES ON PLASTIC SCINTILLATORS USING A ^{137}Cs GAMMA RAY SOURCE

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OUTLINE

1. Introduction
2. Radiation Resistant Scintillators
3. LED Stimulated Recovery
4. Accelerated Beam Tests
5. Summary & Conclusion

Motivation for Particle Detector Development

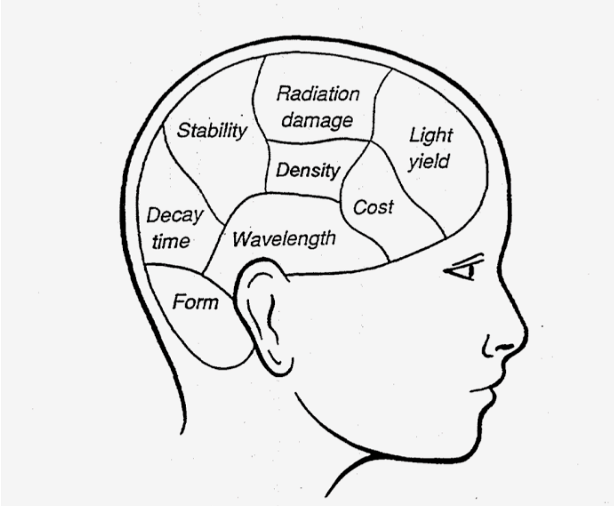


Figure 2. Properties of scintillators to be considered when selecting materials.

What are we looking for?

- ✓ Compact
- ✓ High light yield
- ✓ High resolution
- ✓ Radiation resistant
- ✓ Fast
- ✓ Cost effective particle detectors.

Our goal is:

- to provide the best solution for the CMS Calorimeter Phase II Upgrade and future collider experiments.
- to find/improve the high-performance, radiation-hard: active media and readout components

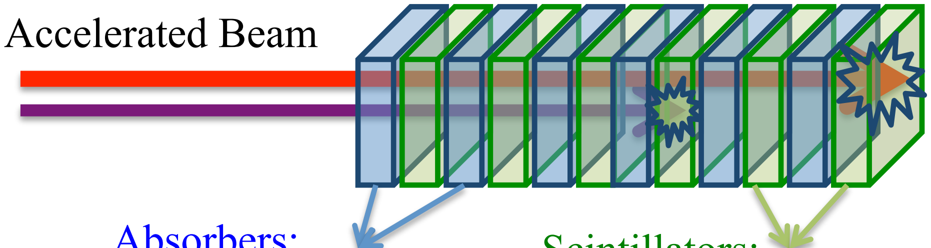
For any particle experiments in general and for CMS in specific

Calorimeter Design

Calorimeters;

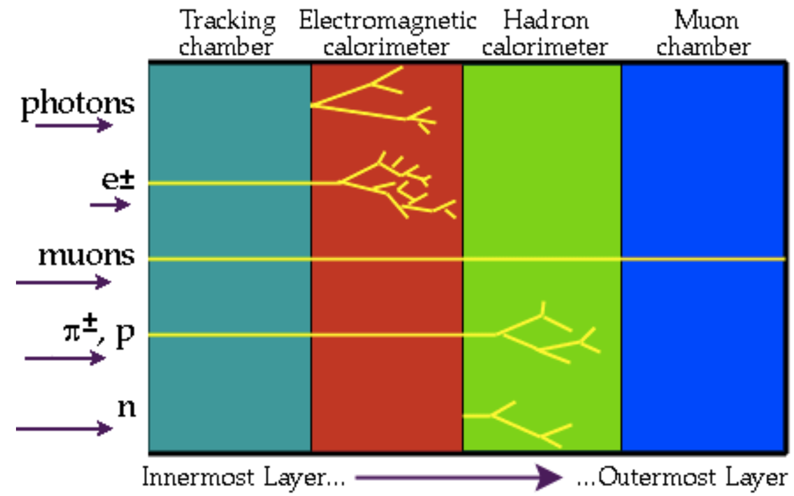
- stop particles to measure the energy of them ($p^{+/-}$, p^{o})
- are too large to absorb as much particle energy as possible

Accelerated Beam

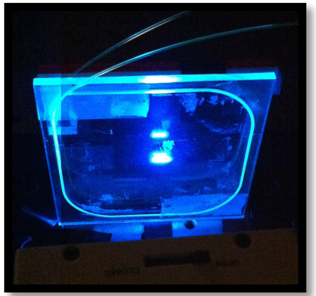


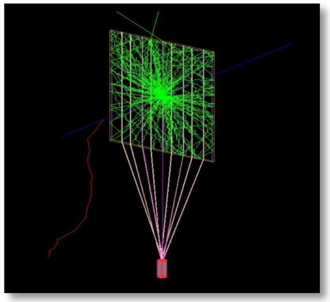
Absorbers:
lead, tungsten, etc.
(slow down particles)

Scintillators:
plastic, quartz, etc.
(produce photons called scintillation)

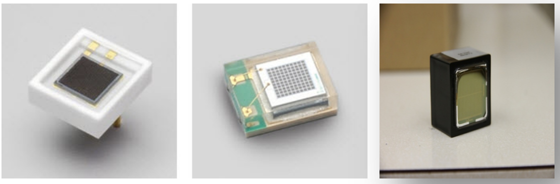


- different geometries:





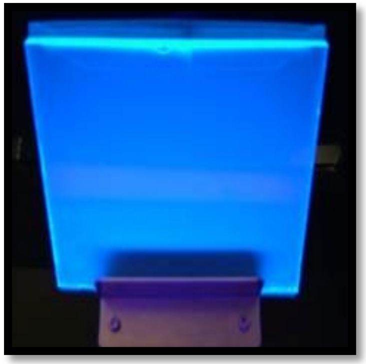
- different photodetectors:

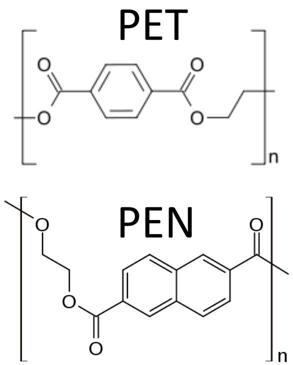


SiPM PMT

Radiation Resistance Key

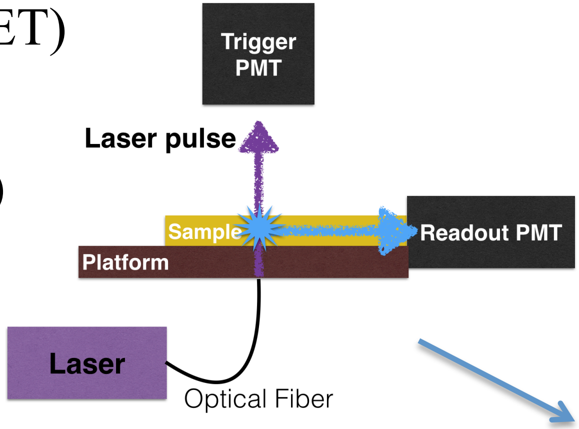
Collision energy and luminosity (# of particles/sec.) are increasing so total radiation level is increasing.

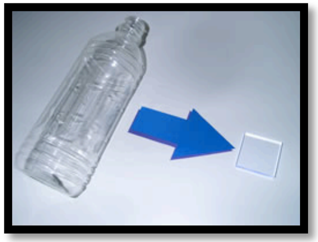


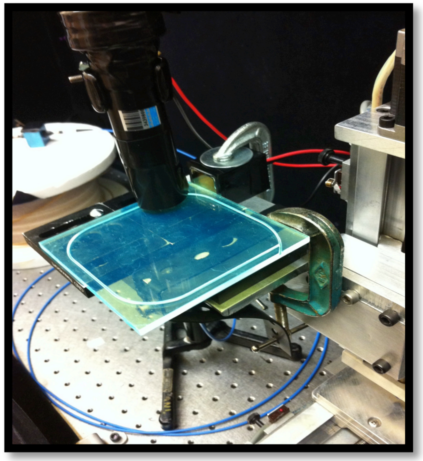


Scintillating Materials: we look at different materials

- Polyethylene Naphthalate (PEN)
- Polyethylene Terephthalate (PET)







PEN:

- ✓ Intrinsic blue scintillation (425 nm)
- ✓ Short decay time

PET:

- ✓ A common type polymer
- ✓ Plastic bottles and as a substrate in thin film solar cells.
- ✓ Emission spectrum of PET peaks at 385 nm [Nakamura, 2013]

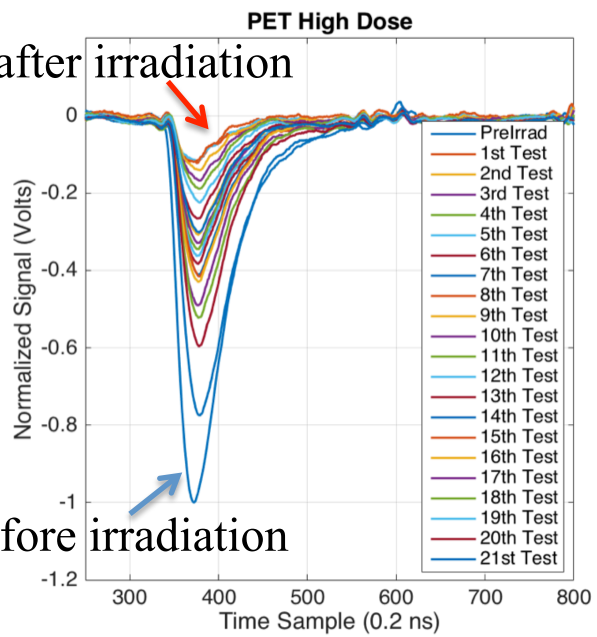
Irradiation of Scintillators

- We irradiated our samples with using ^{137}Cs gamma source at Iowa Rad Core
- 1 Mrad and 10 Mrad

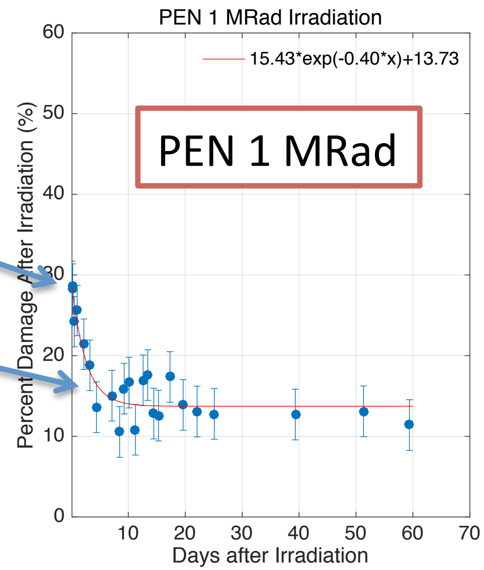
Initial damage

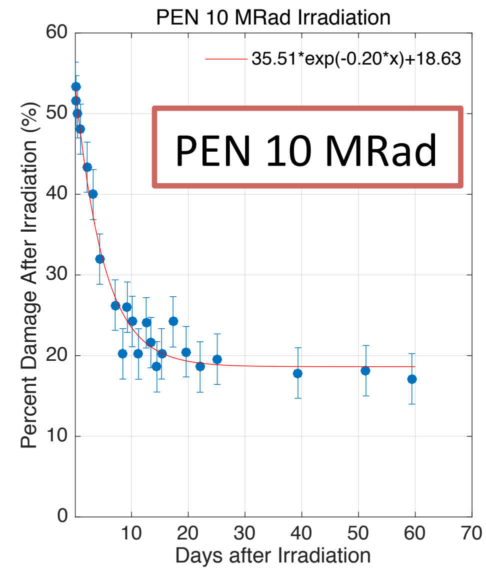
Permanent damage - plateau

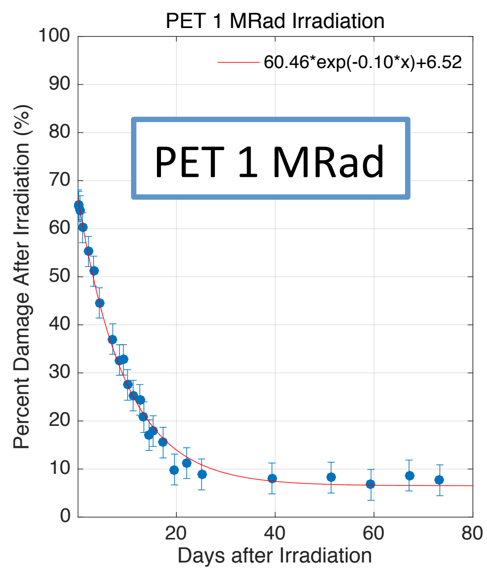
Right after irradiation

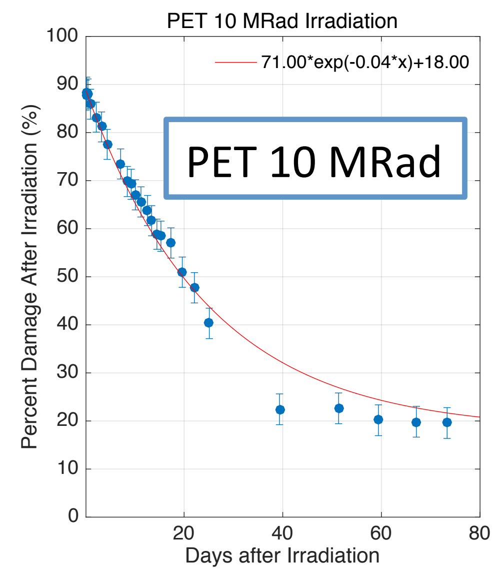


Before irradiation





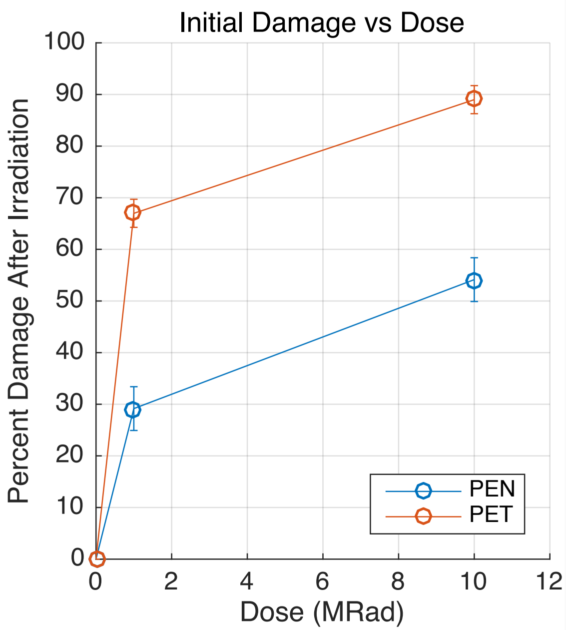




- Damage was calculated in terms of light yield

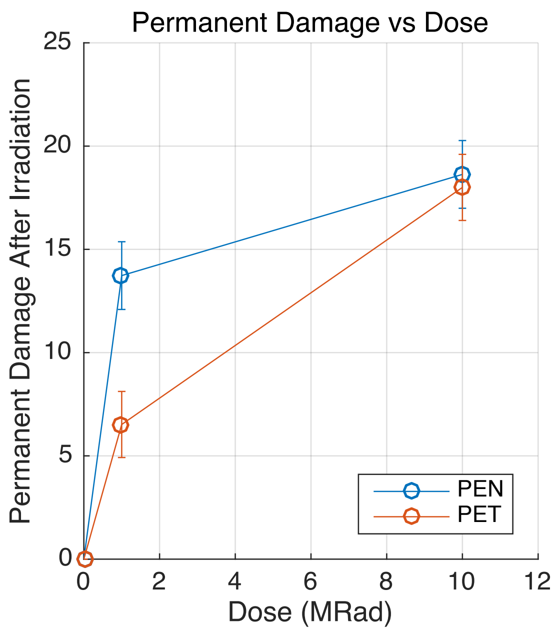
Summary of irradiation results

Initial damage



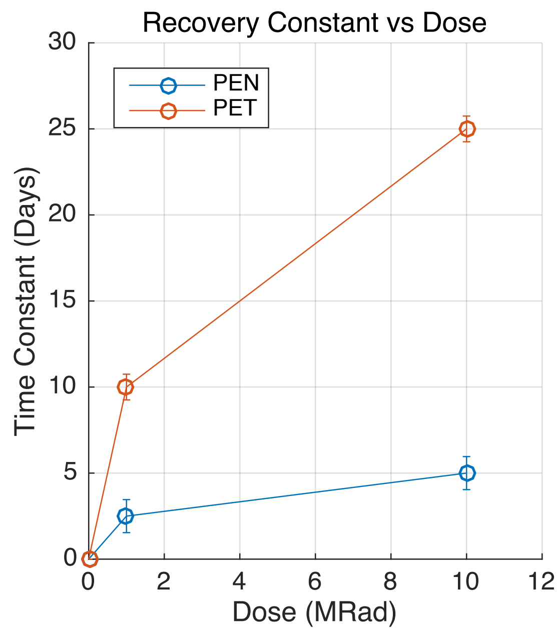
- PET was damaged more than PEN initially

Permanent damage



- Permanent damage was same at 10 MRad

Time for Recovery

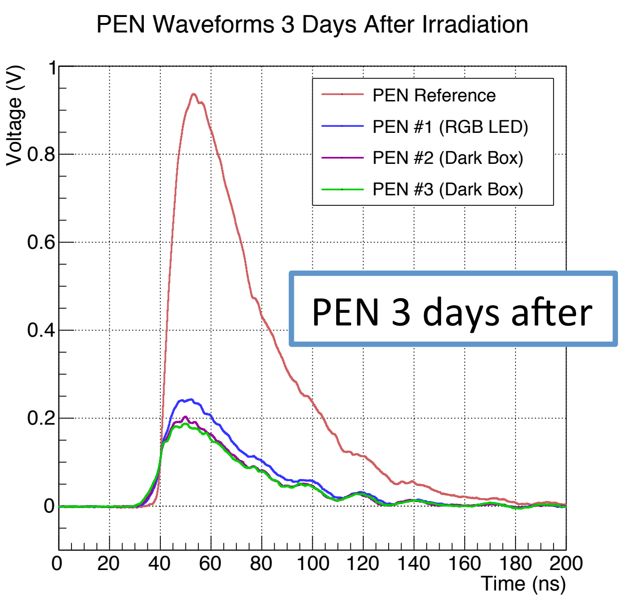


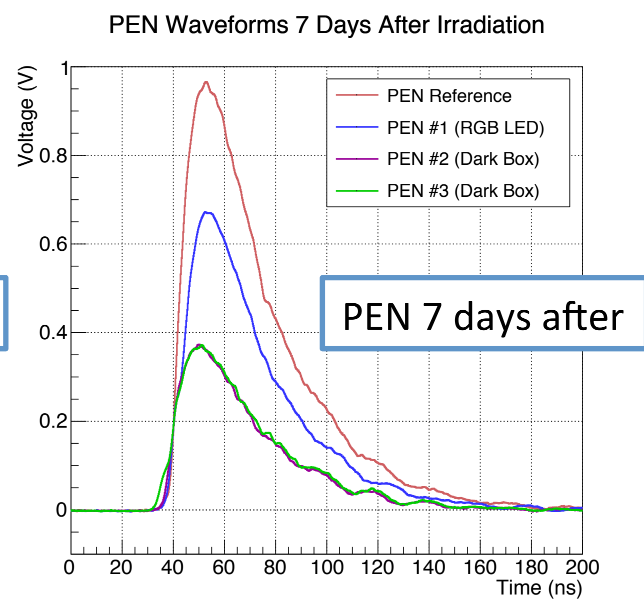
- PEN was recovered in 5 days only and PET in 25 days – so slow

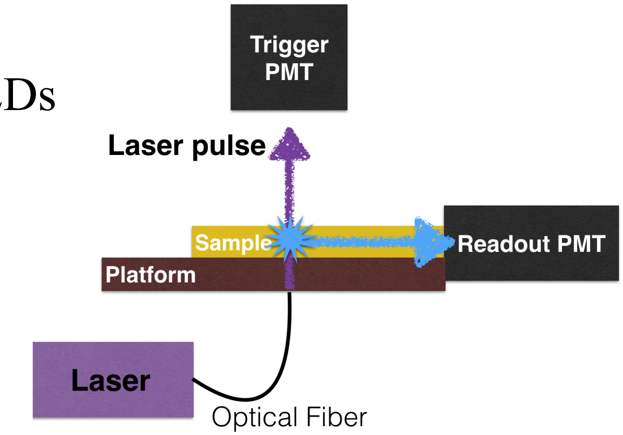
LED Stimulated Recovery

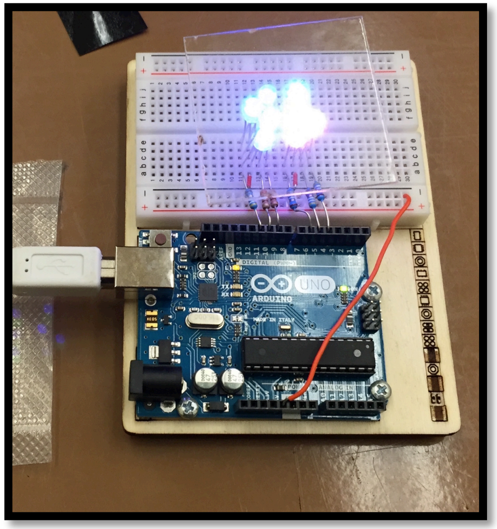
Can we stimulate the recovery of scintillators damaged from radiation?

✓ By using an array of tri-color red, blue, green (RGB) LEDs





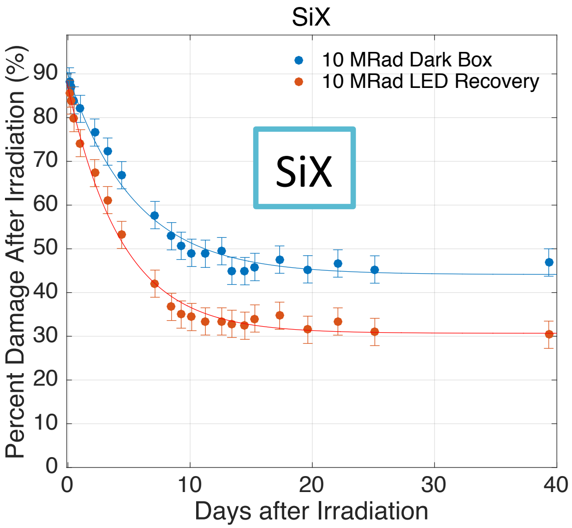




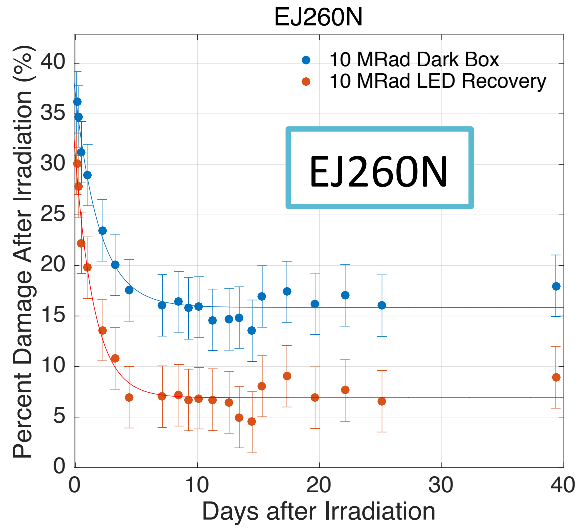
Different Materials:

- Eljen brand EJ-260 (N) and overdoped version EJ2P.
- Lab produced plastic scintillator (SiX)

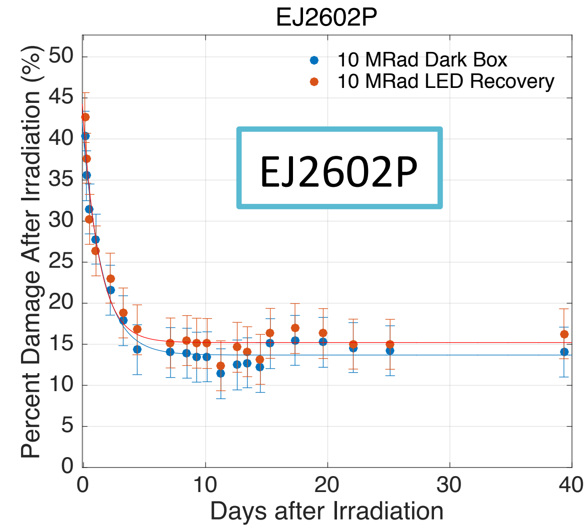
LED Stimulated Recovery



Blue emission



Green emission



Green emission

Tile	'*a*', Total Recovery	'*c*', Permanent Damage
SiX RGB	56.3 ± 2.4%	30.7 ± 1.6%
SiX dark box	45.7 ± 2.5%	44.1 ± 1.9%
EJN RGB	24.0 ± 2.2%	6.92 ± 0.7%
EJN dark box	21.1 ± 1.8%	15.9 ± 0.6%
EJ2P RGB	26.9 ± 3.1%	15.2 ± 0.9%
EJ2P dark box	26.5 ± 2.2%	13.7 ± 0.7%

- SiX showed significant effect, the sample on RGB LED recovering 10% more and faster (4.5 vs 5.5 days)
- Neither EJN and EJ2P showed significant effect.
- 'Blue' scintillators respond to color spectrum but 'green' scintillators are affected very little.

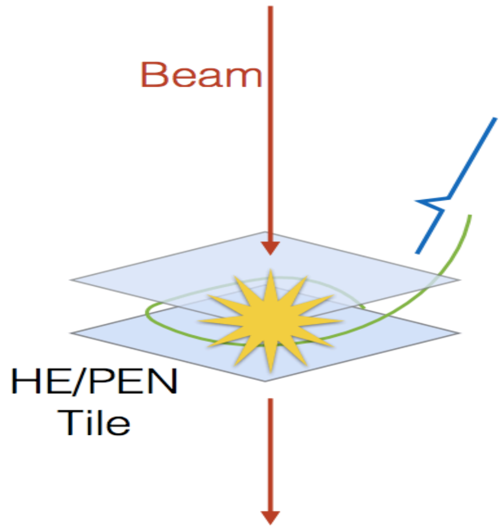
Accelerated Beam Tests

Where?

- CERN Test Beam Area
- Fermilab Test Beam Facility

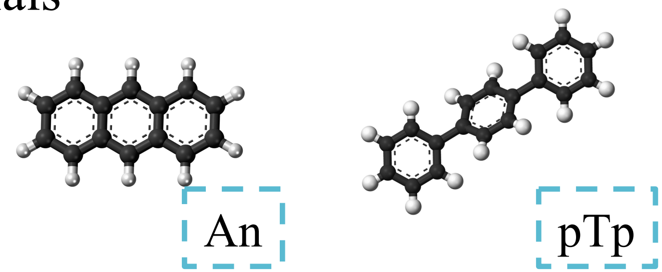
What beam?

- Shower particles: electrons, pions, etc.
- Minimum Ionizing particles: muons, protons, etc.



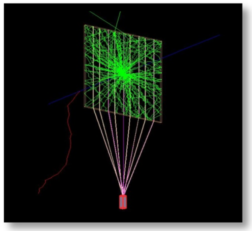
What materials?

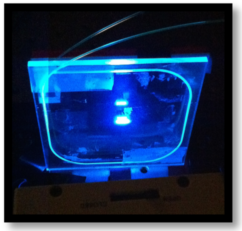
- Quartz plates coated with various organic materials
  - p-Terphenyl (pTp),
  - Gallium-doped Zinc Oxide (ZnO:Ga)
  - Anthracene (An)
- PEN, PET and HEM



What geometry and readout?

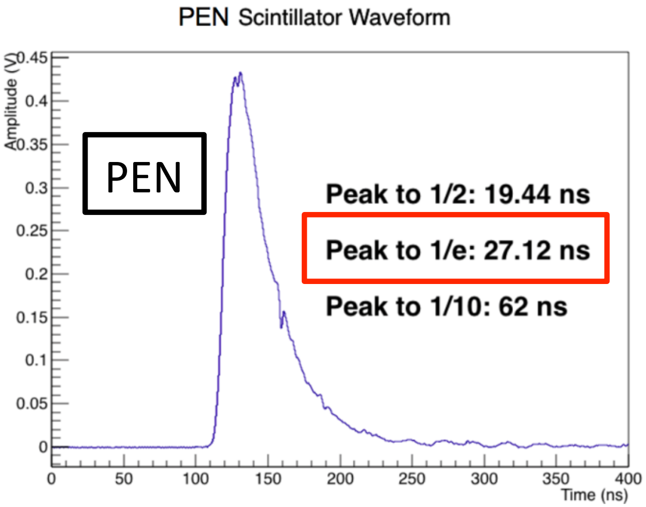
- Sigma & Bar shape
- SiPM, PMT

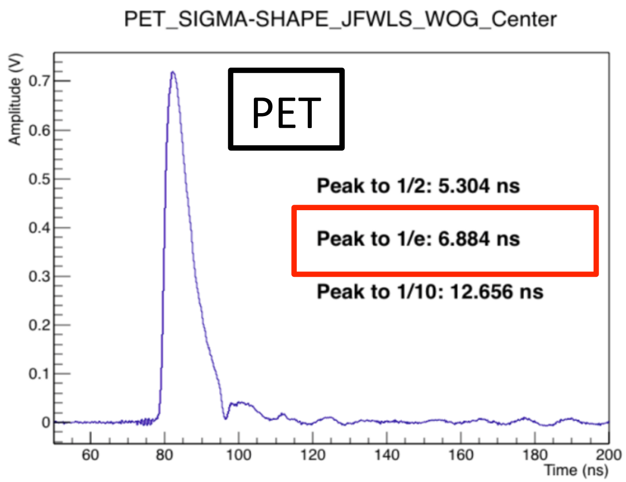




Accelerated Beam Test Results

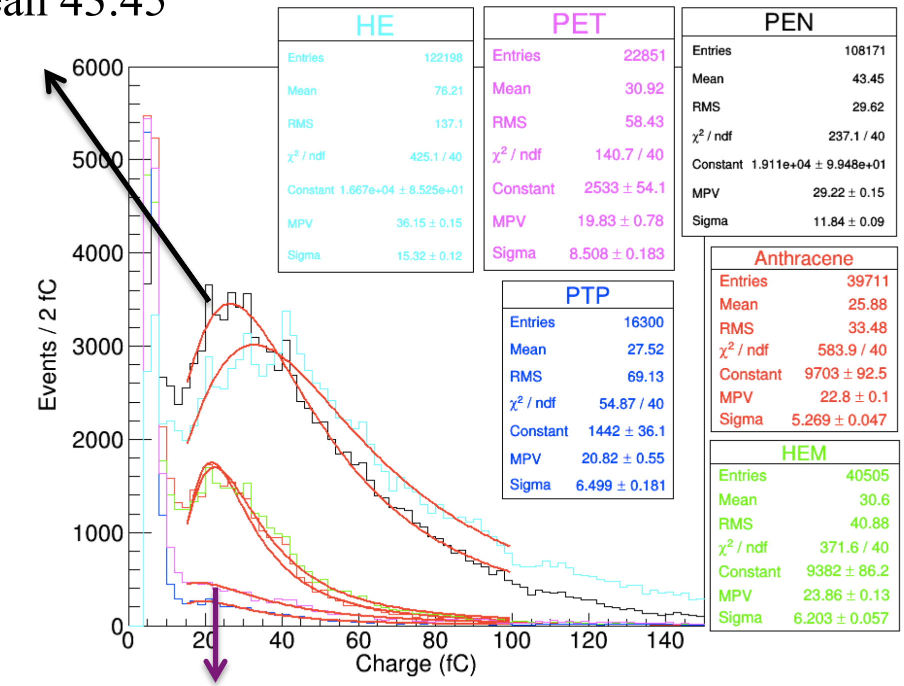
Timing





Light Yield

PEN → Light yield mean 43.45



PET → Light yield mean 30.92

- PET is faster but emits less light. PEN is radiation resistant up to 10 Mrad and it has a significant light yield but its so slow.

Summary & Conclusion

What about a blended sample of PEN and PET?

- It was produced and tested by H. Nakamura, et al. and light yield of the blended substrate was measured 0.85 times that of PEN and much higher than that of PET.

- The blended sample is yet to be investigated for signal timing properties.

Why LED stimulates the recovery and how can they be integrated?

- Progressive research is still underway

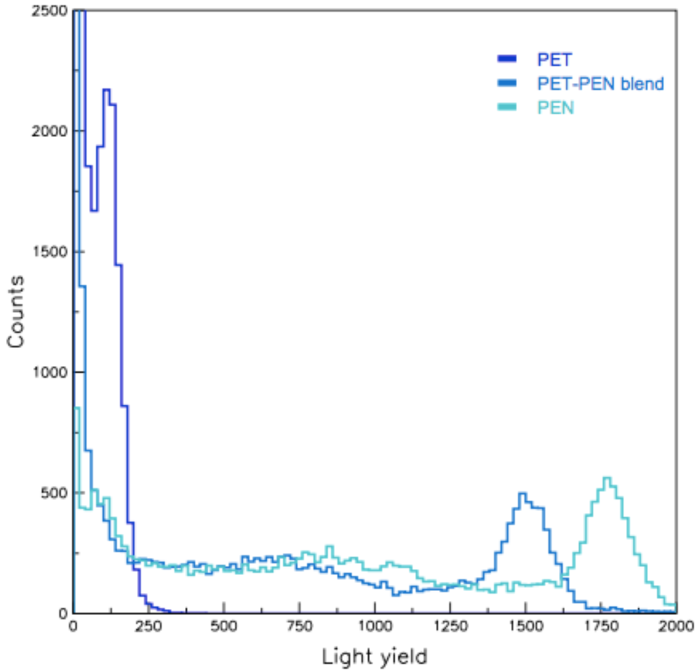


Fig. 5. Light yield distributions for PET, PEN, and the 1:1 blend of PET and PEN.

H. Nakamura et al. / Radiation Measurements 59 (2013) 172-175